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Effect of lumbar paraspinal muscle fatigue on ankle proprioception

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Abstract
Background: Proprioceptive information plays an important role in joint stabilization, body coordination and proper function in activities of daily living. Muscle fatigue may alter active repositioning accuracy and might have an effect on the joint function and predispose to injury.
Objective: This study was conducted to investigate the effect of lumbar paraspinal muscle fatigue on ankle joint repositioning accuracy on healthy subjects and the effect of sex difference on ankle joint active repositioning accuracy before and after lumbar paraspinal muscle fatigue.
Methods: Fifty subjects (males and females) were recruited from the students of faculty of Physical Therapy Cairo University. They were assigned into two equal groups A and B with their mean ages were (25.13±3.8) and (27.93±5.8) years respectively.Ankle joint active repositioning accuracy was measured before and after lumbar paraspinal muscle fatigue for both groups using 3 pro-isokinetic Biodex system.
Results: The study revealed that there was no significant difference in pre and post mean values for lumbar muscle fatigue in ankle joint active repositioning errors in both males and females, where P-values were (0.549, 0.518) respectively while there was significant difference between males and females in ankle joint active repositioning error where P-value was (0.019).
Conclusion: Female ankle joint repositioning accuracy is statistically less accurate compared with male healthy subjects.

Keywords: healthy subjects, lumbar paraspinal muscle, biodex isokinetic system, proprioception, ankle joint and muscle fatigue

Introduction

Proprioception refers to neural cumulative input to the central nervous system (CNS) proceeding from specialized nerve endings called mechanoreceptors [1]. It is the sense of knowing where one's body is in space and is classically comprised of both static and dynamic [2]. It is the body's ability to transmit position sense, interpret the information and respond consciously or unconsciously to stimulation through appropriate execution of posture and movement. It allows the body to maintain stability and orientation during both static and dynamic activities [3].

Information regarding limb awareness, position, force and heaviness is provided by input which is received from the peripheral afferents (muscle spindles, joint receptors, cutaneous receptors and Golgi tendon organs) and this refers to a proprioceptive mechanism [4].

Fatigue is a common non-specific symptom experienced by most people at some point during their lives. It is the enduring, subjective sensation of generalized tiredness or exhaustion [5]. In healthy persons with no history of low back pain (LBP), lumbar paraspinal fatigue resulted in an anteriorly displaced center of pressure and center of mass, indicating a forward-leaning posture and an altered postural control strategy in response to a balance perturbation after isolated lumbar paraspinal fatigue [6].

Fatigue alters the force capacity of muscles, it is a complex and diverse phenomenon involving neural and muscular mechanisms. At the ankle, it decreases the sense of position and the control of balance. For example, Lundin *et al*., 1993 [7] have examined how plantar flexor and dorsi flexor fatigue induced through an isokinetic protocol affected the control of balance. They reported a significant increase in medio-lateral (M-L) body sway oscillations amplitude compared with a no fatigued state. Similar observations have been reported by others [8]. Studies have examined the postural effect of the lumbar extensor muscle fatigue under normal somatosensory conditions from the foot and ankle considering the important role of the foot and ankle somatosensory inputs in the regulation of postural sway during quiet standing [9].

Effect of lumbar paraspinal muscle fatigue on ankle joint proprioception has not been clearly established. If this effect can be reliably established, rehabilitation protocols could be altered to include proprioceptive training of the ankle joints in cases that excessive fatigability of the back extensor muscles is common as in patients with chronic low back trouble. Also the effect of gender has to be investigated as some investigators had found no effect of gender on fatigue [10], while others reported that sex difference can affect the fatigue process [11,12].

The purpose of the study was to investigate the effect of lumbar paraspinal muscle fatigue on ankle joint repositioning accuracy in healthy subjects and the effect of sex difference on ankle joint repositioning accuracy.

Materials and Methods
Participants
Fifty normal subjects of both sexes were participated in this study. Subjects with back disorder preventing physical stress and back deformity, subjects with cardiovascular or neurological problems, athletic subjects, smokers and diabetic patients, subjects with history of ankle injury or surgery or joint diseases were excluded from the study. Subjects were recruited in voluntary base from the students of faculty of physical therapy, Cairo University. They were assigned equally into group A (male) and group B (female). There mean ages were (25.13±3.8) and (27.93±5.8) years respectively and their mean body mass indices were (23±1.4) and (23.6±1.5) kg/ m² respectively. All volunteers signed a written consent for participation.

Design of the study
A pre-test posttest design was used where ankle joint active repositioning accuracy was the independent variable while lumbar paraspinal muscle fatigue and sex were the dependent variables. The study was conducted within 4 months, measurements were taken twice pre and posttest.

Instrumentation
Biodex system 3 Pro Multijoint system isokinetic dynamometer (Biodex Medical Inc, Shirley, NY) was used to measure ankle joint active repositioning accuracy. It was found to be valid and accurate research tool [13, 14].

Procedures
Pretesting and familiarization
Prior to testing, each subject was given two test runs to be familiar with the dynamometer device. Before data collection, each participant underwent two familiarization trials, first with the eyes closed as the tested extremity was allowed to passively move to the target angle (30°) [15, 16] and then it was held for 10 s as teaching process for the participant so that he or she could memorize the position. The limb was then allowed to return to the starting position by the apparatus [16, 17].

Ankle active repositioning accuracy measurement
The subject data was entered to computer program database. Test protocol was set from the software program; proprioception unilateral protocol with ankle plantar/dorsi flexion, type of test was chosen (active repositioning test) with speed 30^0/sec with three repetitions for each test.

Range of motion (ROM) was set (from 45^0 Plantar flexion to 20^0 Dorsi flexion) using the control panel [15, 16].Target angles were set at 30° of plantar flexion [17]. The particular angle was chosen because it will be commonly used in the relevant literature and also because it falls within the most usual ROMs utilized during activities.

Initially, the anatomical reference (target) angle (30^0) was set, and then the participant move and held at the starting angle (0^0) by using the hold / resume (HR) button. The tested limb was allowed to move to the target angle (30^0) plantar flexion, actively by the participant then hold for 10sec as teaching process for the subject [18].

Then the limb allowed returning to the starting angle by the apparatus. The participant allowed returning to the target angle (30^0) plantar flexion actively. When the participant felt that he reached the target angle actively, the examiner stopped the apparatus using the HR button. Three trials were recorded, each beginning from the starting position /angle. There was a period of rest equal to 30 seconds between each trial.

Absolute angular error was recorded as the participant perceived the reference angle. The mean angular differences of the three trials between the target angle position and the participant's perceived end range position was recorded (in degrees) as the deficit in repositioning accuracy was used in statistical analysis [19].

Lumbar fatigue program
The examiner set the parameters of the isokinetic dynamometer on the fatigue model. The subject was seated on the trunk flexion/extension unit of the Biodex system. The spinal range of motion was adjusted between 80 degree flexion and 10 degree hyperextension as recorded through the Biodex system. The subject performed isokinetic lumbar flexion and extension at a speed of 60^0/sec [20] and was instructed to perform maximal effort. The mean value of maximal voluntary contraction (Peak torque) of the lumbar extensor was obtained, the subject continued in exercise until the lumbar extensor peak torque dropped below 50% for 3 consecutive repetitions.

Statistical analysis
Data were collected and analyzed statistically using SPSS 20 program. Descriptive statistics (mean and standard deviation) were used in age, height, weight and BMI. Inferential statistics using paired t-test to illustrate the effect of lumbar paraspinal muscle fatigue on ankle joint active repositioning accuracy within each group. Unpaired t-test to illustrate the effect of sex difference on active ankle repositioning accuracy between groups. The significance level was set at P-value less than 0.05.

Results
The study sample consisted of 50 healthy individuals divided equally into two groups (males and females). The male group had a mean age and BMI of 25.13 ± 3.8 years and 23 ± 1.4 kg/m2, respectively. The female group had a mean age and BMI of 27.93 ± 5.8 years and 23.6±1.5 respectively. There was no significant difference between two groups in their mean age and BMI where P-values were 0.133 and 0.257 respectively. Demographic characteristics are presented in Table 1.

Table 2 shows the mean scores of ankle repositioning errors for group A before and after lumbar extensors muscle fatigue. The paired t-test proved that there was no significant difference in ankle joint repositioning accuracy where P = 0.549 and mean ± SD values were 2.41±1.01, 2.64±1.02 degrees respectively also there was no significant difference in ankle joint repositioning errors for group B before and after lumbar extensors muscle fatigue where mean ± SD values were 3.56 ± 1. 3, 3.6 ± 1.2 degrees respectively and P = 0.518.

Table 3 shows the mean scores of ankle repositioning errors for both groups. There was a significant difference (P=0.019) in ankle joint repositioning errors between male and female.

The mean±SD values for males and females were 2.41±1.01 and 3.56±1.3 respectively.

Table 1: General Characteristics of subjects in both groups

General characteristics	Age (years)	Weight (kg)	Height (cm)	BMI (kg/m^2)
Group A (Male) Mean ±SD	25.13±3.8	62.73±8.2	163.13±6.8	23±1.4
Group B(Female) Mean ±SD	27.93±5.8	63±7.3	162.9±6.7	23.6±1.5
t-value	-1.54	-0.094	0.08	-1.156
P-value	0.133	0.926	0.937	0.257
Significance	N.S	N.S	N.S	N.S

N.S: Non-significant

Table 2: Pre and post lumbar fatigue mean values of subject's ankle repositioning errors for both groups.

Ankle proprioception error (deg.)	Group A (Male) n=25	Group B (Female) n=25
Pre lumbar fatigue Mean ±SD	2.41±1.01	3.56±1.3
Post lumbar fatigue Mean ±SD	2.64±1.02	3.6±1.2
t-value	-0.608	-0.656
p-value	0.549	0.518
Significance	N.S	N.S

N.S: No significant

Table 3: Ankle repositioning error measurements for both groups

Ankle repositioning errors (deg.)	Group A (Male) n=25	Group B (Female) n=25
Mean ±SD	2.41±1.01	3.56±1.3
t-value	-2.42	
p-value	0.019	
Significance	S	

S: significant

Discussion

This study was conducted to investigate the effect of lumbar paraspinal muscle fatigue on ankle joint active repositioning accuracy in healthy subjects and the effect of sex difference on ankle joint proprioception using Biodex system 3 pro-isokinetic dynamometer. The study revealed that there was no significant differences between pre and post lumbar fatigue on ankle joint repositioning errors for males and females where P-values were 0.549,0.518 respectively but for sex there was significant difference between male and female in ankle repositioning errors where P-value was 0.019.

Our result revealed that lumbar muscle fatigue has no effect on ankle joint repositioning errors and this may happen as body segments work together to generate force and this force was used to hold or move a body part, because they are separated regions; lumbar muscle fatigue didn't affect the ankle joint proprioception [21].

Our result revealed that there was higher reduction in the ankle repositioning accuracy in females compared with males may be explained as female soft tissues have estrogen receptors which are responsive to female sex hormones [22]. Increased estradiol concentrations decrease collagen synthesis and fibroblast proliferation where estrogen has great direct effects on soft tissue strength and muscle function [23–24].

The current findings go in line with those for Rania [25] who examined sex differences of knee joint repositioning accuracy in 64 healthy subjects that was divided into two equal groups and revealed that there was significant effect of sex difference between males and females on the knee proprioception. Also the current findings agreed with a study of Nagai *et al*. [26] who examined sex differences in knee internal/external rotation proprioception and the study revealed that women demonstrated more diminished threshold of passive motion detection toward internal rotation as compared with men.

On the other hand according to sex differences, our findings agreed withKent-Braunet *et al*. [27] who revealed that differences in fatigability across gender could occur as a result of differences in neural drive, fiber type composition, contractile function, muscle membrane excitability, metabolic capacity or muscle and blood flow [27]. In addition to the effects of activation and metabolism on muscle performance, the degree of fatigue that develops during exercise may be affected by muscle size and consequently vascular constriction during contraction.

Also our findings agreed with those of Burnes *et al*. [28] who revealed that gender, sex hormones and muscle fiber types can influence the fatigability of muscle. In human subjects, males have greater overall strength but can fatigue to a greater extent than females in a task-dependent manner. When males and females are matched for strength, women fatigued less than men during intermittent contractions but performed similarly during sustained low-intensity contractions as males.

On the other hand our findings were in disagreement with those of of Vafadar *et al*. [29] who examined 28 healthy individuals (14 females and 14 males) for absolute repositioning error of the shoulder joint and found that there was no significant difference between men. Moreover, Artz *et al*. [30] examined 40 healthy volunteers aged 19–59 years for repositioning errors in upright and flexed neck postures during tests performed in 25, 50, and 75% cervical flexion; none of these measures were influenced by sex.

Limitation of study

This study was limited small sample so as we couldn't generalize the results also the Biodex isokinetic dynamometer cannot measure fractions of degrees.

Conclusion

On the basis of the finding of this study, female ankle joint repositioning accuracy is statistically less accurate compared with male healthy subjects and this may imply that ankle repositioning sensitivity might potentially contribute to the high incidence of ankle injury in females compared with males. Exploring possible sex differences in ankle repositioning accuracy can increase our knowledge about sex differences in mechanisms of ankle injury, assist clinicians in developing more effective ankle injury interventions programs by focusing on active repositioning training during rehabilitation especially for females and provide scientists a framework for answering important questions related to ankle injuries, prevention and treatment.

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